ЕКОЛОГІЧНА БЕЗПЕКА НАВКОЛИШНЬОГО СЕРЕДОВИЩА

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THE CONCEPT OF CREATING UNIVERSAL SYSTEMS FOR THE ENVIRONMENTAL CERTIFICATION OF TRANSPORT DIESELS BASED ON MINI- AND MICROTUNNELS

Purpose. Creation of a scientific and practical basis for the development on the basis of mini and micro tunnels of universal low-cost systems for the environmental certification of transport diesel engines in terms of the mass emission of particulate matter with exhaust gases. **Methods.** Analysis and synthesis of information when studying the systems of ecological certification of diesel engines, physical and mathematical modeling, experimental research of working processes, technical characteristics and efficiency indicators of tunnels. **Results.** The technical characteristics of mini and micro-tunnels as control systems for mass emissions of diesel particulate matter are considered. The concept of the creation of universal mini- and microtunnels is proposed based on the principles of increasing their compactness, dynamism, management efficiency and accuracy. **Conclusions**. The results of theoretical and experimental researches and developments on increasing the universality of mini- and microtunnels are presented: mathematical models of work processes, resulting errors and performance indicators of tunnel; new isokinetic and compensation methods for controlling exhaust gas samples; prototypes of a minitunnule with an isokinetic sampler MT-1, microtunnels MKT-1 and MKT-2; test benches for studies of thermal processes in tunnels, isokinetic and compensation sampling regimes; results experimental development of certification procedures for measuring emissions of particulate matter from automotive, tractor and diesel locomotives.

Keywords: diesel, exhaust gases, solid particles, environmental certification, minitunnel, microtunnel, universality

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КОНЦЕПЦІЯ СТВОРЕННЯ НА БАЗІ МІНІ- ТА МІКРОТУНЕЛІВ УНІВЕРСАЛЬНИХ СИСТЕМ ЕКОЛОГІЧНОЇ СЕРТИФІКАЦІЇ ТРАНСПОРТНИХ ДИЗЕЛІВ

Мета. Створення науково-практичної бази для розробки на базі міні- та мікротунелів універсальних недорогих систем екологічної сертифікації транспортних дизелів за показником масового викиду твердих частинок з відпрацьованими газами. **Методи:** Аналіз та синтез інформації, фізичне та математичне моделювання, експериментальні дослідження. **Результати.** Запропоновано концепцію створення універсальних міні- та мікротунелів на основі принципів підвищення їх компактності, динамічності, ефективності керування і точності вимірювального обладнання. **Висновки.** Представлено результати теоретичних та експериментальних досліджень та розробок щодо підвищення універсальності міні- та мікротунелів: математичні моделі робочих процесів, нові методи контролю проби, макетні зразки вимірювачів МТ-1, МКТ-1, МКТ-2, тощо.

Ключові слова: дизель, відпрацьовані гази, тверді частинки, екологічна сертифікація, мінітунель, мікротунель, універсальність

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КОНЦЕПЦИЯ СОЗДАНИЯ НА БАЗЕ МИНИ- И МИКРОТУННЕЛЕЙ УНИВЕРСАЛЬНЫХ СИСТЕМ ЭКОЛОГИЧЕСКОЙ СЕРТИФИКАЦИИ ТРАНСПОРТНЫХ ДИЗЕЛЕЙ

Цель. Создание научно-практической базы для разработки на базе мини- и микротуннелей универсальных недорогих систем экологической сертификации транспортных дизелей по показателю массового выброса твердых частиц с отработавшими газами. **Методы.** Анализ и синтез информации, физическое и математическое моделирование, экспериментальные исследования. **Результаты.** Предложена концепция создания универсальных мини- и микротуннелей на основе принципов повышения их компактности, динамичности, эффективности управления и точности. **Выводы.** Представлены результаты теоретичес-

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ких и экспериментальных исследований и разработок по повышению универсальности мини- и микротуннелей: математические модели рабочих процессов, новые методы контроля проб отработавших газов, макетные образцы измерителей МТ-1, МКТ-1, МКТ-2 и др.

Ключевые слова: дизель, отработавшие газы, твердые частицы, экологическая сертификация, минитуннель, микротуннель, универсальность

Introduction

Today, when creating transport engines, special attention is paid to their environmental performance, which characterizes the negative impact of these power plants on the environment. This is especially true for diesel engines, which, by their operating principle, are more toxic than gasoline and gas engines.

Among the most dangerous substances contained in the exhaust gases of diesel engines are solid particles (PM), which determine how all the material collected on special filtering means after passing through them exhaust gas diluted with pure air to a temperature not exceeding 52 °C [1].

The mass emission of PM with exhaust gases from diesel engines is a normative parameter, for the determination of which special measuring systems are used – diluting tunnels, the most effective of which are mini tunnels (MT) and microtunnels (MKT) at their price and convenience in operation.

At the present stage, the ecologization of engine building in the design of tunnels solve the urgent problem of increasing their universality – the possibility of using diesel engines of various types in testing. In order to solve this problem, the author, based on his own experience in the development and operation of tunnels, proposed the concept of creating universal systems for the environmental certification of transport diesel engines based on MT and MKT.

Object and methods of research

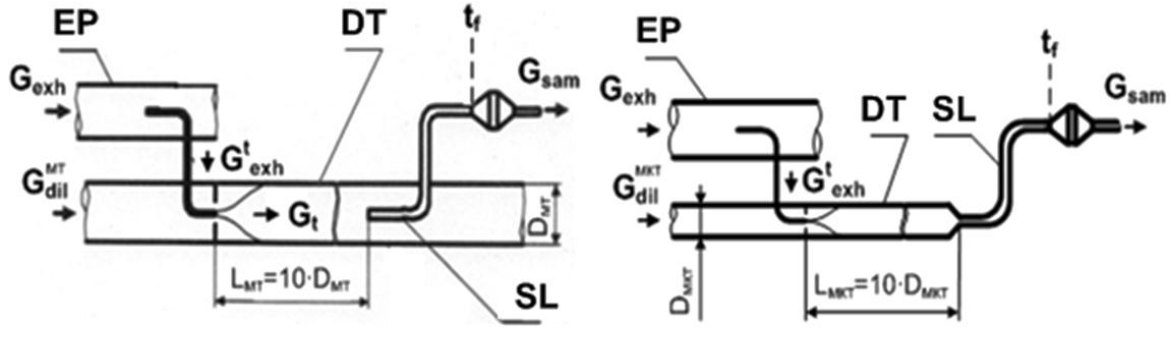
General characteristics of the layout schemes of mini and microtunnels.

MT and MKT relate to partial-flow diesel fuel sampling systems, which are more mobile and cheaper than reference full-flow tunnels.

In MT sampling modules – diluting exhaust gas with air and sampling PM for filters have different gas blowers with mass flow rates of 10 ... 50 g/s and 1,2 ... 2,5 g/s, respectively; the dimensions of the dilution tunnel for exhaust gas – the tunnel of these systems - diameter (D) × length (L) are 7.5 ... 10 × 75 ... 100 cm (Fig. 1,a).

In the MKT, the sample preparation and sampling points for PM on the filters are combined into one module with a common gas blower, whose productivity is 1,2 ... 2,5 g/s; this allows to reduce the overall dimensions of the tunnel to D × L = 2,5 ... 4,0 × 25 ... 40 cm (Fig. 1,b).

MT and MKT are used to determine the mass, specific and average operating PM emissions during arbitrary, research and certification tests of diesel engines, which are carried out in accordance with the requirements of regulatory documents [1-3].



a) b)

EP – exhaust pipe of a diesel engine; DT – diluting tunnel; SL – sampling line PM
a) minitunnel; b) microtunnel.

Fig. 1 – Schematic diagrams of partial-flow control systems for emissions of diesel PM

The concept of creating universal diesel certification systems based on mini and microtunnels is based on four basic principles:

1) *increase of compactness of equipment* due to minimization of mass-dimensions parameters of tunnels; this will increase their mobility and convenience in operation, reduce the performance of gas blowers, the energy and economic costs of their operation;

2) *increasing the dynamism of the systems for sample preparation and sampling of PM* by using low-inertia methods for monitoring the work processes of these systems; this will enable the use of MT and MKT in performing highly dynamic test cycles – the European Transient Cycle (ETC), the Worldwide Transient Vehicle Cycle (WTVC), the Worldwide heavy-duty transient cycle (WHTC) and other [4-6];

3) *increasing the accuracy of the gravimetric measurement method* by reducing its instrumental and methodological errors; this will allow to ensure the required accuracy of MT and MKT in conditions of decreasing standards for PM emissions from diesel engines;

4) *modernization of the algorithm of operation and software of tunnels* by taking into account existing and prospective testing procedures for various diesel engines and data processing techniques; this will expand the scope of application of MT and MKT to all types of transport diesels.

Results and discussion

With the purpose of creating a scientific and practical basis for increasing the universality of MT and MKT, the results of theoretical and experimental studies were systematized by specialists of the O.M. Beketov National University of Urban Economy in Kharkiv, National Technical University "Kharkov Polytechnic Institute" and Volodymyr Dahl East Ukrainian National University in the period 2003-2017; the results of the research can be divided into the following groups.

Mathematical models for definition of technical characteristics and efficiency indicators of tunnels:

– *mathematical model of the thermal state of the sample in the tunnel*, which allows to determine the required parameters of the dilution of exhaust gas by air in the tunnel – dilution factor and sample temperature before the filter for the selection of PM [7, 8]; these parameters must comply with the conditions for dilution of exhaust gas in a full-flow tunnel, which eliminates the methodological error of the gravimetric method for controlling diesel emissions of PM;

– *mathematical model for determining the resulting error in the measurement of mass emissions of PM* as a sum of its instrumental and methodological components [9, 10]; this model allows to estimate the accuracy of MT and MKT and to determine the influence of errors in measuring equipment and conditions of dilution of exhaust gas in the tunnel on it;

– *a complex mathematical model for evaluating tunnel efficiency* by three criteria: the accuracy of measurements, the required fuel consumption for testing and the cost of the test procedure [11]; on the basis of this model, optimization of technical and operational parameters of MT and MKT can be carried out according to the specified criteria.

New methods for controlling the sample of exhaust gas and the concentration of PM in the tunnel:

– *compensation method for controlling the exhaust gas sample*, which is taken from the diesel exhaust system [12]; this method provides the required accuracy of measurements and is 5 ... 8 times cheaper than the known analogue – the differential method, which is used in the microtunnel AVL SPC 472;

– *the method of dynamic control of PM emissions with an optoelectronic sensor element*, which allows to determine the instantaneous values of PM concentrations in exhaust gas during the operation of the diesel engine under steady and unsteady test conditions [13];

– *method of accelerated measurement of mass emission of PM with exhaust gas of diesel engine*, which allows to determine this environmental indicator with the minimum possible time expenditure, provided that the required accuracy of measurements is provided [14]; this method is most in demand in the ecological diagnostics of dimensional diesel engines – diesel locomotives, ships, etc., whose tests are characterized by considerable fuel costs and have a high cost.

Batch samples of mass emission control systems for PM emissions from diesel engines, which are developed in accordance with the requirements of international standards [1-3]:

- *minitunel with isokinetic sampler MT-1* (Fig. 2), which has the following technical characteristics: tunnel dimensions – D × L = 8,5

× 100 cm; the capacity of gas blowers: the dilution module of exhaust gas is 25 g/s, the sampling line of PM is 1,2 g/s; the selection regime for exhaust gas is isokinetic [15];

- *microtunnels: MKT-1* – non-automated system *and MKT-2* – automated system (Fig. 3), which have the following technical characteristics: tunnel dimensions - D × L = 3,0 × 30 cm; the total gas blowing capacity of the exhaust gas dilution module and the PM sampling line – 1,2 g/s; modes of selection of exhaust gases – isokinetic, proportional, constant; MKT-2 control mode – using a PC using specially developed software (Fig. 4) [16,17].

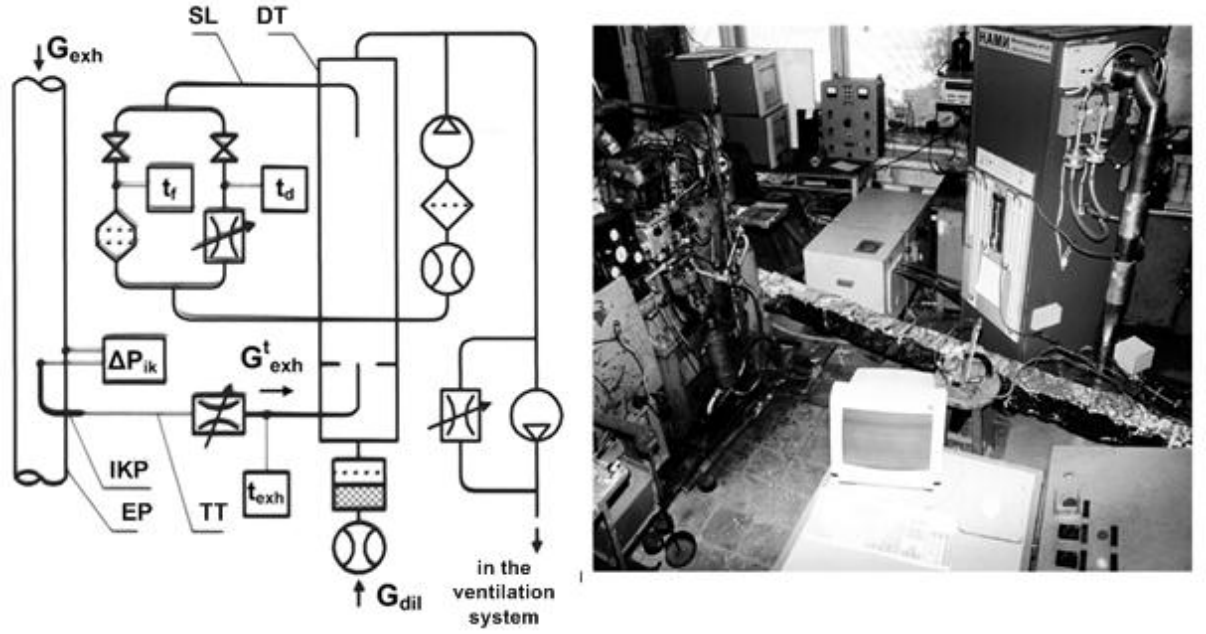


Fig. 2 – Schematic diagram and general view of the MT-1 minitunnel

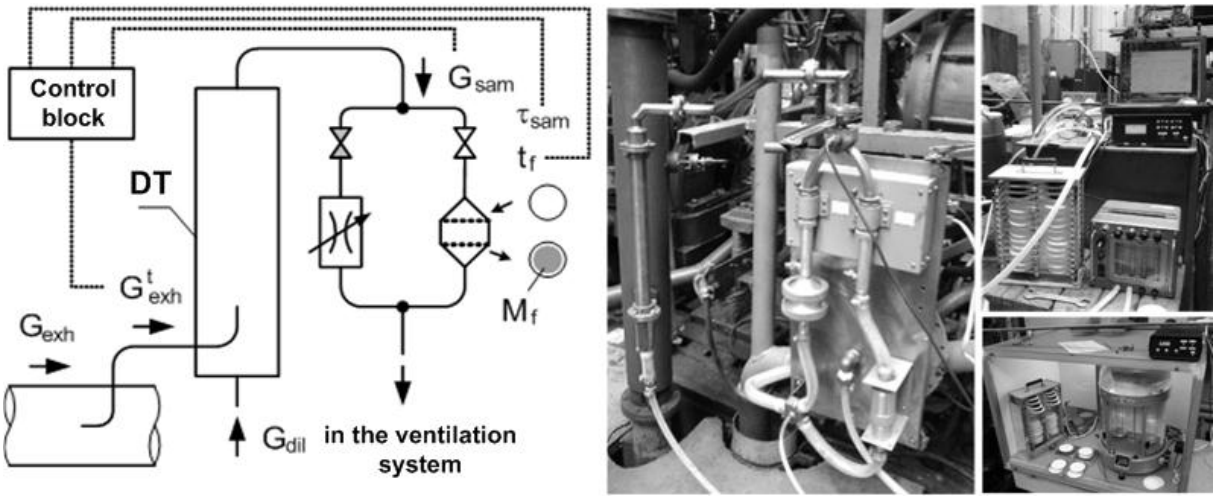


Fig. 3 – Schematic diagram and general view of the microtunnel MKT-2 and its elements

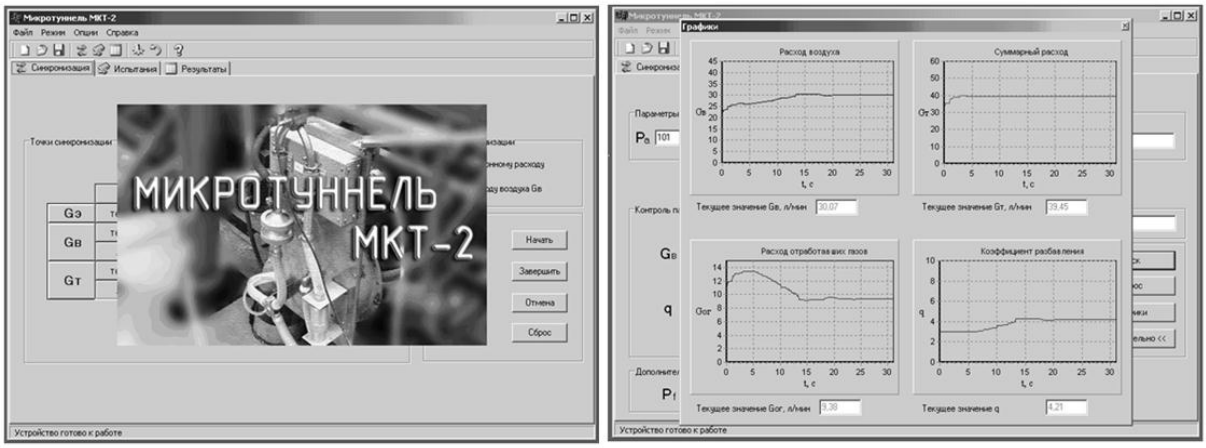


Fig. 4 – Software of microtunnel MKT-2

Test benches for research of working processes in tunnels:

– stand for research of thermal processes in tunnels (Fig. 5); at this stand the process of heat transfer through the wall of the tunnel was investigated and the criterial equation of this process in dimensionless form was established [18];

– a non-motorized stand for studies of the isokinetic and compensation mode of exhaust gas sampling (Fig. 6); at this booth, the conditions for using the isokinetic sampler of the MT-1 mini-tunnel were experimentally determined and confirmed the practical suitability of the compensation method for controlling the sample of exhaust gases [19].

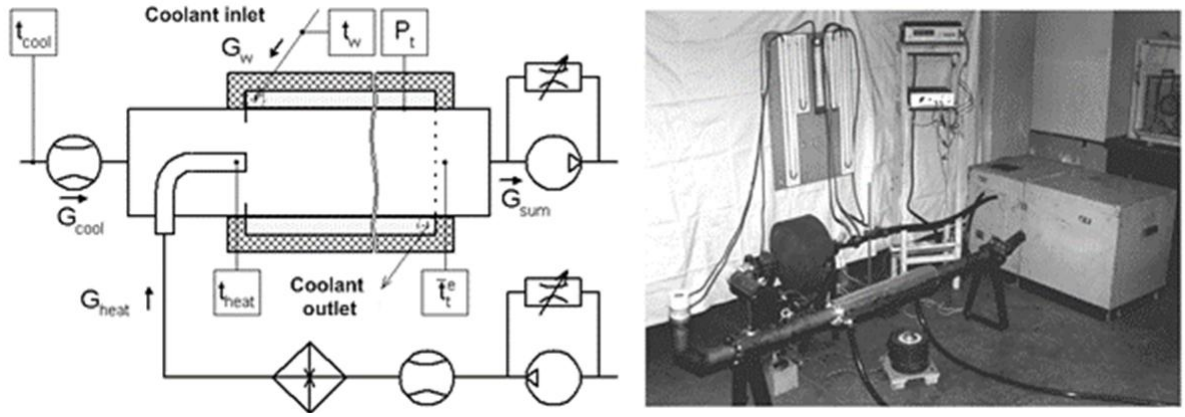


Fig. 5 – Schematic diagram and general view of the stand for studying thermal processes in tunnels

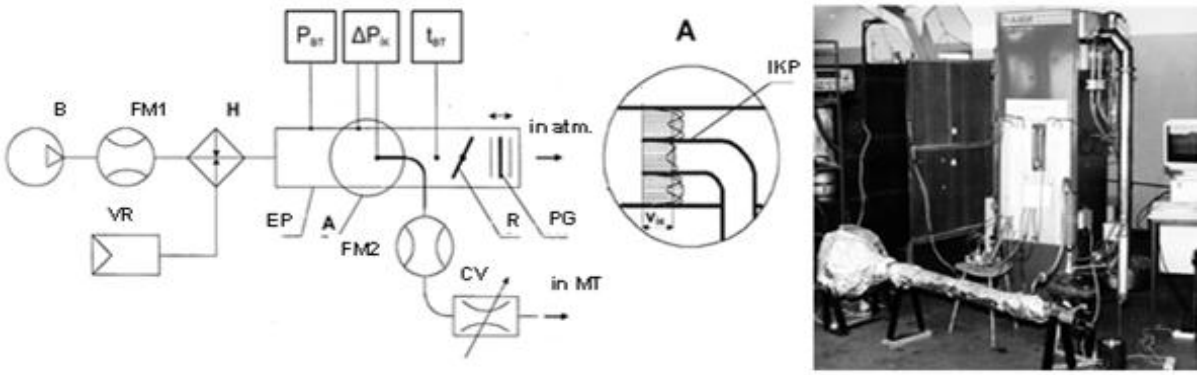


Fig. 6 – Schematic diagram and general view of a non-motorized test bench

The results of experimental testing of the procedures for certification tests of diesel engines: automobile 4CHN12/14 – 13-step R-49 cycle and ESC cycle, tractor D-242 – 8-stage R-96 cycle and diesel 6DN – ISO-8178F and DSTU 32.001-94 cycles (Fig. 7) [20, 21].

On the basis of the above research results, a modern domestic measurement system for the environmental diagnosis and certification of transport diesel engines for various purposes on the standardized mass emission of PM can be created based.

Conclusions

1.The concept of creation on the basis of mobile and inexpensive mini and microtunnels of universal systems of ecological certification of transport diesels, which allow to determine the normalized emissions of solids with exhaust gases of automobile, tractor, diesel, marine and other diesel engines, is proposed. At the heart of the concept are the principles of increasing the compactness, dynamism, accuracy and efficiency of measuring equipment management.

2. The results of theoretical and experimental research and development, which constitute the scientific and practical basis for increasing the universality of the mini and microtunnels are presented: *mathematical*

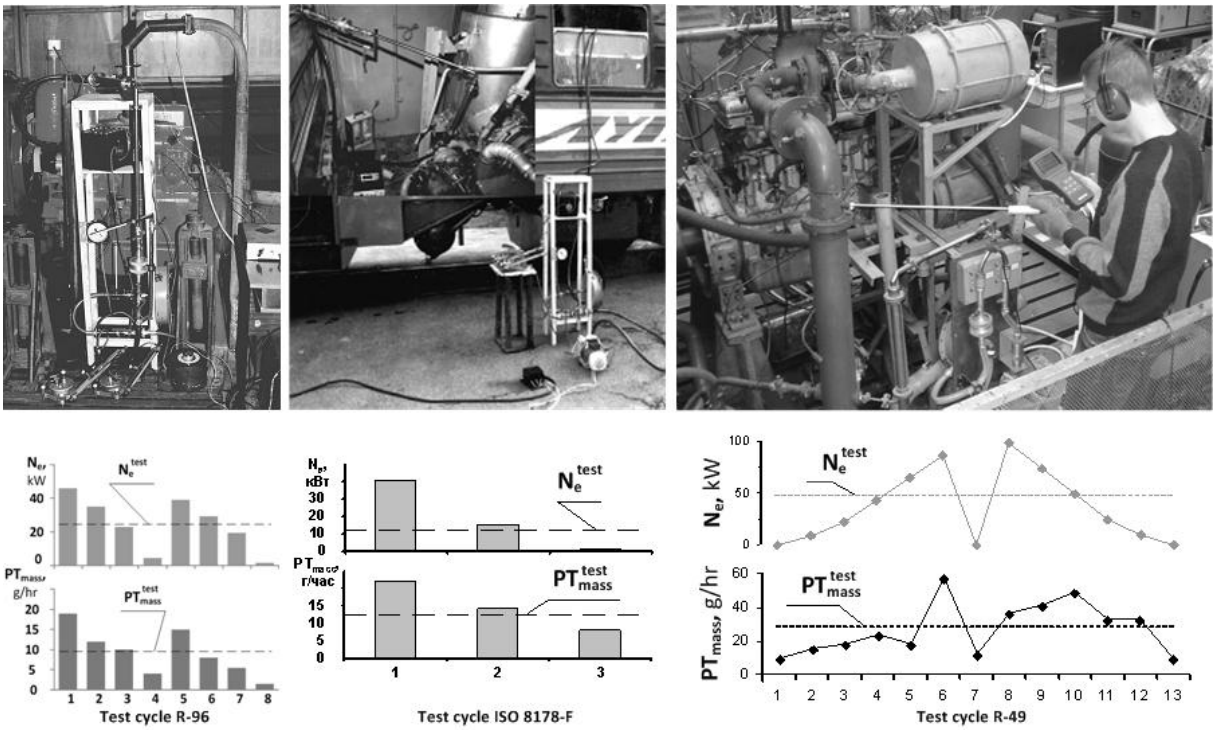


Fig. 7 – Environmental testing of tractor, locomotive and automobile diesels with MKT-1 and MKT-2

models: the resulting error of measurements of the emission of solid particles, the thermal state of the gas sample in the tunnel, the complex estimation of the efficiency of the tunnel by the criteria of accuracy and economic application efficiency; *methods:* compensated sampling of exhaust gases, dynamic control of solid particles using an optoelectronic sensing element, accelerated measurement of particulate emissions; *model samples:* miniunnel MT-1 with isokinetic sampler, microtubules MKT-1 and MKT-2, *test benches* for research on tunnel thermal processes, isokinetic and compensatory regimes of exhaust gas sampling, *results of experimental testing of certification procedures* for determination of particulate emissions from automobile, tractor and locomotive diesel engines.

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